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Detection of Local/Regional Events in Kuwait Using Next-Generation Detection Algorithms

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Detection of Local/Regional Events in Kuwait Using Next-Generation Detection Algorithms

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INTODUCTION

Seismic networks around the world use conventional triggering algorithms to detect seismic signals in order to locate local/regional seismic events. Kuwait National Seismological Network (KNSN) of Kuwait Institute of Scientific Research (KISR) is operating seven broad-band and short-period three-component stations in Kuwait. The network is equipped with Nanometrics digitizers and uses Antelope and Guralp acquisition software for processing and archiving the data. In this study, we selected 10 days of archived hourly-segmented continuous data of five stations (Figure 1) and 250 days of continuous recording at MIB. For the temporary deployment our selection criteria was based on KNSN catalog intensity for the period of time we test the method. An autonomous event detection and clustering framework is employed to test a more complete catalog of this short period of time. The goal is to illustrate the effectiveness of the technique and pursue the framework for longer period of time.

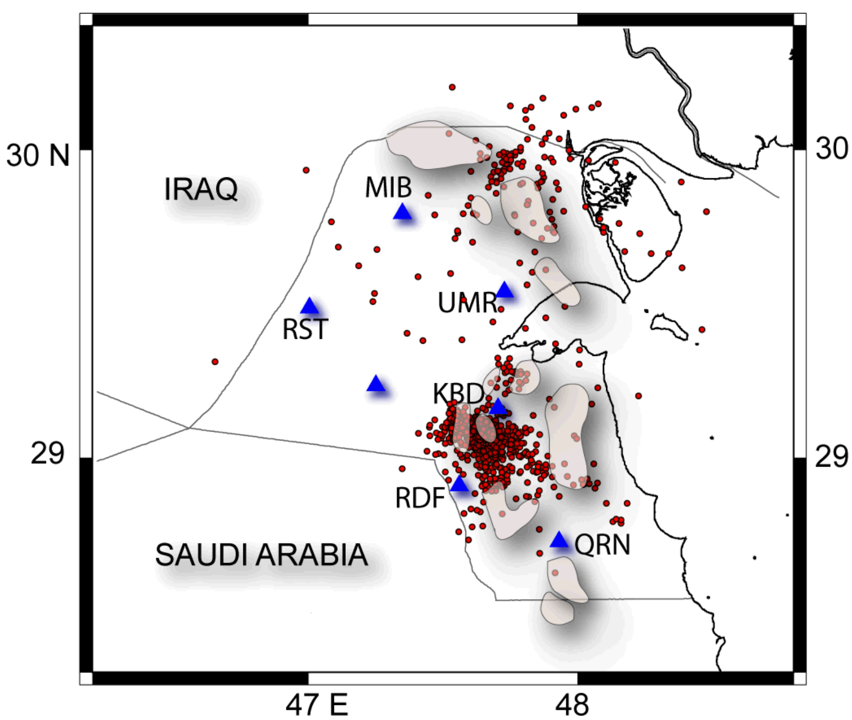


Figure 1. KISR/ISC events from the catalog (2000-2013) and seismic station locations. Shaded area represents the oil fields.

METHOD and RESULTS

Subspace detectors are generalizations of waveform correlation detectors that permit a degree of variation in the signals being detected. Subspace detectors are getting more commonly used for seismological applications because seismic signals rarely repeat exactly. In this project we use subspace detectors to search data streams for repeating events (Harris and Dodge, 2011). The variation of related waveforms can be represented in a waveform basis constructed from a sample ensemble of such waveforms. The basis is constructed by assembling ensemble waveforms in sampled (digital) form as columns of a data matrix, then performing a singular value decomposition (SVD) of the data matrix to extract a low-rank orthonormal set of spanning vectors (left singular vectors) (Harris and Dodge, 2011). Prior to assembling the data matrix, the waveforms are aligned using shifts obtained by maximizing the cross-correlation functions of the event waveforms. The rank is estimated as the number of singular values needed to represent a given fraction (typically 90%) of the energy in the eigenspectrum of the data correlation matrix. Correlation detectors are rank-one subspace detectors; that is, the signal subspace is characterized by a single basis waveform.

The framework is a java-based application that was developed as a collaborative effort between Lawrence Livermore National Laboratory (LLNL) and NORSAR. A block diagram highlighting the framework's core functionality is shown in Figure 2. The framework uses power (STA/LTA) detectors to detect events with new waveform patterns, and automatically creates correlation detectors to search for additional occurrences of events with those patterns. The framework maintains a pool of such empirically-derived correlation detectors, which may be updated upon the detection of new signals approximately matching the patterns. It groups signal detections based on waveform similarity and stores event affiliation information in a relational database.

All framework detections are tagged with an identification number (detector ID) that represents new or previously observed signal types (Figure 2). The database can be mined to study the various aspects of the sequence. Detector IDs can be grouped and associated detections counted to identify event clusters. Processing can be initiated using stored detectors and reconfigured to use a lower detection threshold. This allows waveform templates built during later periods of the sequence to be applied to earlier portions of the sequence. Typically this results in the detection of many low SNR signals that were missed in the initial pass.

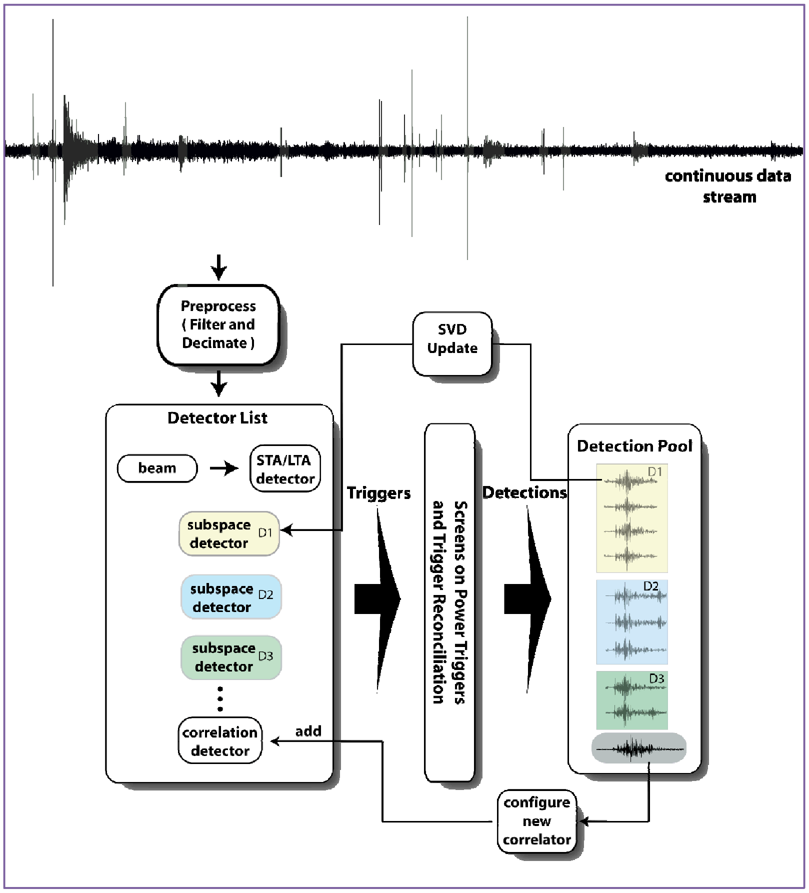


Figure 2 Flow diagram of the framework.

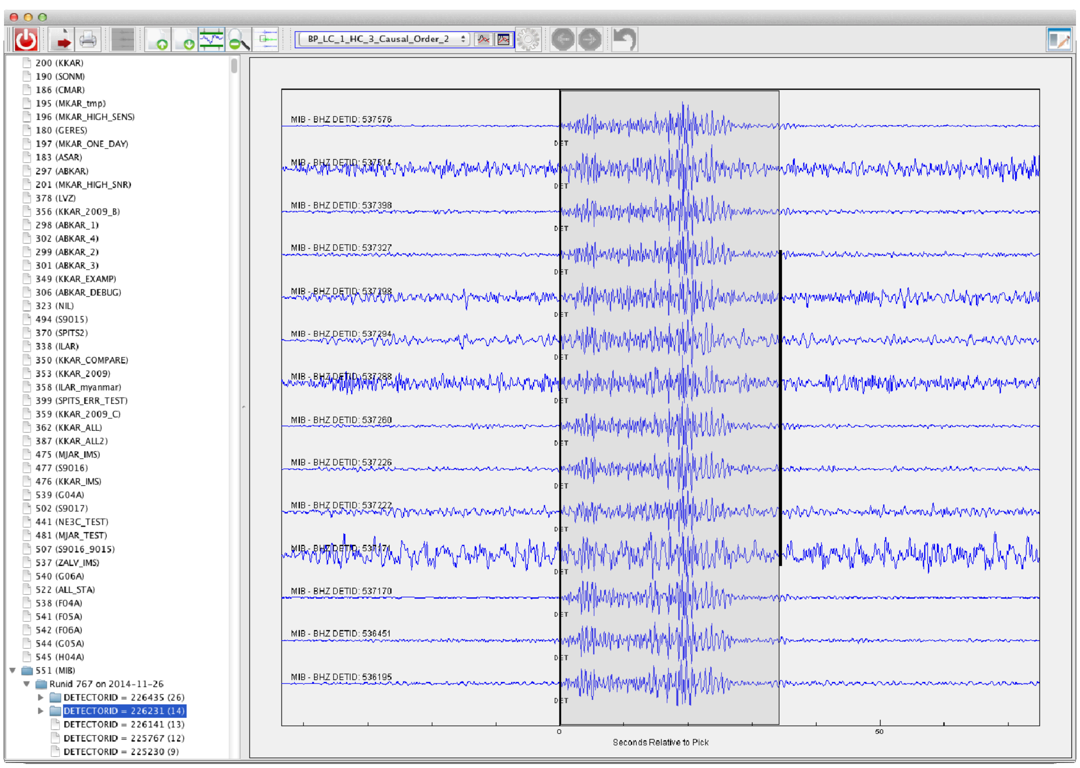
We used data from Kuwait National Seismic Network (KNSN) (Figure 1) to process and test this technique. The list of stations and their specification used in this study are shown in Table 1.

Longitude	**Latitude**	**Elevation**	**DAS**	**Station name (Location)**	**Broad Band**	**Short Period**
47.691481	29.176428	116	9011	KBD	1-3	
47.551167	28.924589	177	9013	RDF (Radifah)	1-3	4-6
46.997936	29.500378	214	9015	RST (Umm Ar Ruwaysat)	1-3	4-6
47.340050	29.802197	126	9016	MIB (Mutribah)	1-3	
47.716219	29.553303	79	9017	UMR (Umm Ar Rimam)	1-3	

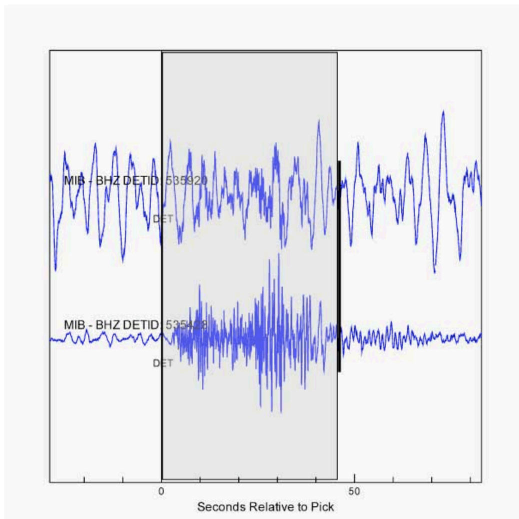
Table 1. Station specifications of KNSN

We used the archived data which was in GCF format which we converted to MiniSEED and SAC for 10 days of data. We did not use horizontals for now. The MIB station belongs to LLNL uses one of the KNSN vaults and co-located at the KNSN network MIB station. Signal is digitized with Kinematrics Q330S with Guralp CMG 3ESP sensor (1,20,100SPS). For the MIB station, the framework detected 2461 detections among 2195 detectors with 114 detectors having 2 or more detections using 250 days of continuous data. For 10 days of KNSN data (KBD, RDF, UMR and MIB) resulted in 31 detectors and 56 detections. Figure 3a shows the framework snapshot and one of the detectors with the largest detection number. Figure 3b,c ,d shows 3 different detectors in local and regional distances. As it was spanned for longer time, the noise will be significantly reduced and the detection templates are more likely to stand out for actual events instead of noise or random detections.

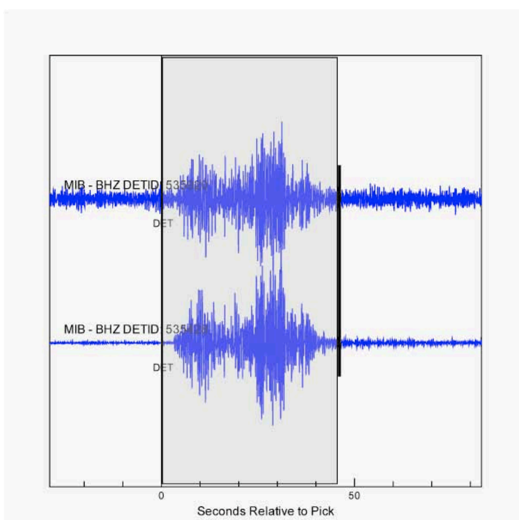
a)



b)

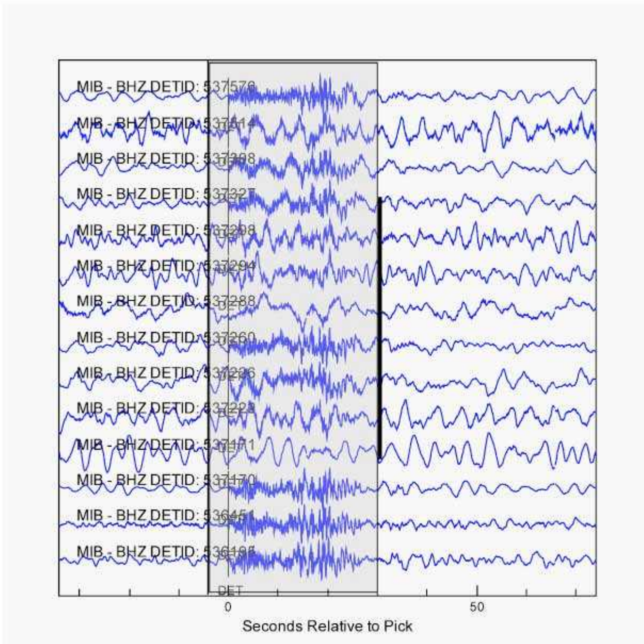


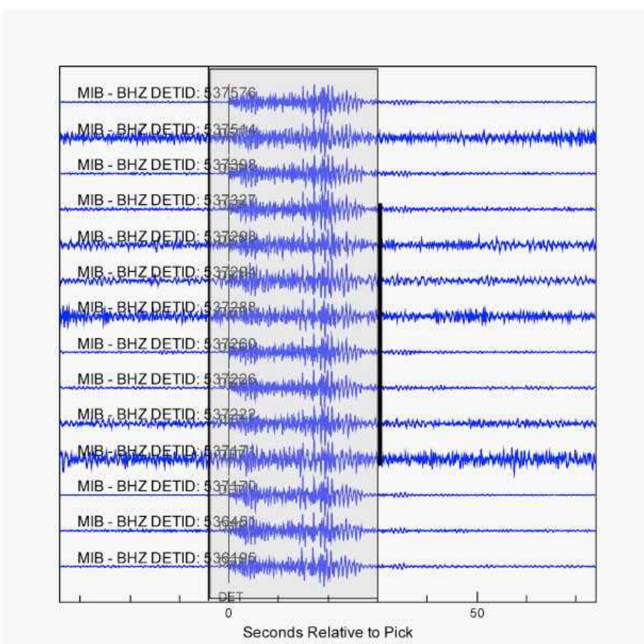
MIB - BHZ DETID 535920
DET
MIB - BHZ DETID
DET
0
50
Seconds Relative to Pick



MIB - BHZ DETID
DET
MIB - BHZ DETID
DET
0
50
Seconds Relative to Pick

c)


MIB - BHZ DETID: 537576
MIB - BHZ DETID: 537514
MIB - BHZ DETID: 537398
MIB - BHZ DETID: 537327
MIB - BHZ DETID: 537298
MIB - BHZ DETID: 537294
MIB - BHZ DETID: 537288
MIB - BHZ DETID: 537260
MIB - BHZ DETID: 537226
MIB - BHZ DETID: 537222
MIB - BHZ DETID: 537171
MIB - BHZ DETID: 537170
MIB - BHZ DETID: 536451
MIB - BHZ DETID: 536196
DET
0
50
Seconds Relative to Pick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MIB - BHZ DETID: 537171
MIB - BHZ DETID: 537170
MIB - BHZ DETID: 536451
MIB - BHZ DETID: 536196
DET
0
50
Seconds Relative to Pick

d)

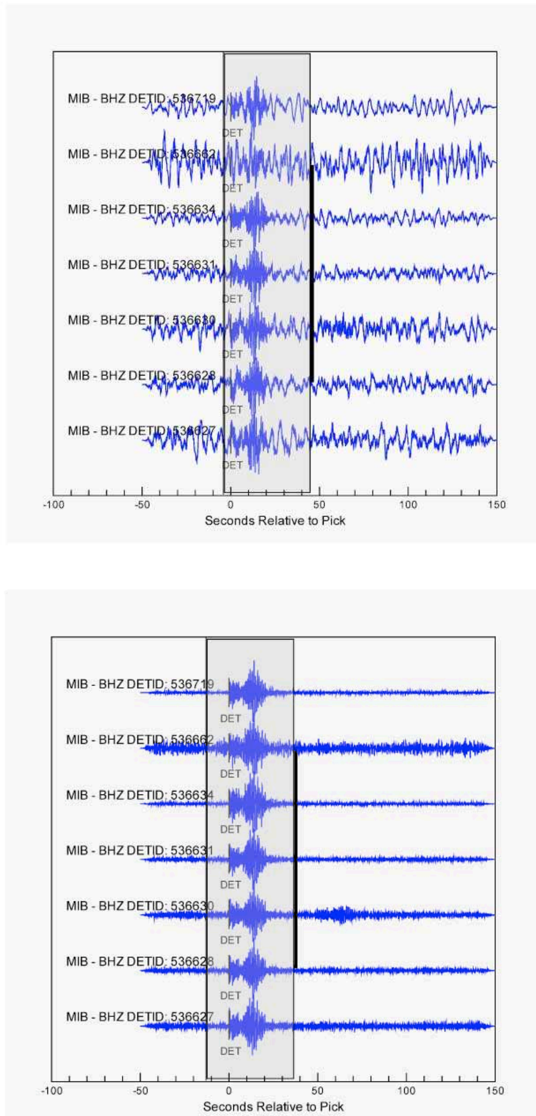

Figure 3. Examples of 4 detectors. Figure 3a is a snapshot from the framework software. Lower panels are filtered at 1-8Hz.

CONCLUSIONS

We tested the effectiveness of subspace detectors using data from KNSN network for a short period (10 days) of time. Longer time span was used for one station of LLNL (MIB) in Kuwait. Results from longer time detection analysis resulted in fairly good detectors that was able to extract events that were identified with conventional methods (e.g. STA/LTA) which is regularly used in regular operations of network acquisition algorithms (Antelope, Guralp, Nanometrics..etc). Using data from local network of KNSN has proven the power of detectors even for a short period of time. We found that higher efficiencies can be obtained by reprocessing the data for a longer period of time that will produce maturing suites of detectors. We propose to extend this work for longer term

REFERENCES

Harris, D. (2006). Subspace detectors: Theory, Lawrence Livermore Natl. Lab. Rep. UCRL-TR-222758, 46 pp., Lawrence Livermore Natl. Lab., Livermore, California (Available at http://www.llnl.gov/tid/lof/documents/pdf/335299.pdf)

Harris, D.B., Dodge, D.A.: An autonomous system for grouping events in a developing aftershock sequence. Bulletin of the Seismological Society of America 101(2), 763–774 (2011). DOI 10.1785/0120100103